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PATENT #6
D. Scott
3-25-00

IN THE UNITED STATES PATENT
AND TRADEMARK OFFICE

Applicants: Drury et al. Serial No.: 09/426,087 Filed: October 22, 1999 For: DROPLET DEPOSITION APPARATUS Group Art Unit: 2853 Examiner: To be assigned	I hereby certify that this paper is being deposited with the United States Postal Service as first class mail, postage prepaid, in an envelope addressed to: Assistant Commissioner for Patents, Washington, DC 20231 on this date: January 20, 2000 James P. Zeller Reg. No. 28,491

SUBMISSION OF PRIORITY DOCUMENT

Assistant Commissioner for Patents
Washington, DC 20231

Sir:

Submitted herewith is a certified copy of UK application No. 9823264.8 filed October 24, 1998, the priority of which is claimed under 35 U.S.C. § 119.

Respectfully submitted,

MARSHALL, O'TOOLE, GERSTEIN,
MURRAY & BORUN

January 20, 2000

By

James P. Zeller
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I also certify that the attached copy of the request for grant of a Patent (Form 1/77) bears an amendment, effected by this office, following a request by the applicant and agreed to by the Comptroller-General.

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The Patent Office

Cardiff Road
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1. Your reference

X339

2. Patent application number *(The Patent Office will fill in this part)*

9823264.8

24 OCT 1998

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

Xaar Technology Limited
Science Park
Milton Road
Cambridge
CB4 4FD

Patents ADP number *(if you know it)*

7301872001

If the applicant is a corporate body, give the country/state of its incorporation

UK

4. Title of the invention

Droplet Deposition Apparatus

5. Name of your agent *(if you have one)*

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

Ian ~~Hartwell~~
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~~Science Park~~
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MATHYS + SQUIRE
100 GRAYS INN ROAD
LONDON
WC1X 8AL

Patents ADP number *(if you know it)*

663840002

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Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application	Date of filing *(day / month / year)*

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   a) any applicant named in part 3 is not an inventor, or
   b) there is an inventor who is not named as an applicant, or
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Continuation sheets of this form	-----
Description	12
Claim(s)	4
Abstract	-----
Drawing(s)	5 +5 - 10

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Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	-----
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11. I/We request the grant of a patent on the basis of this application.

Signature I. Hartwell Date 23/10/98

12. Name and daytime telephone number of person to contact in the United Kingdom — Ian Hartwell (01223) 423663

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Droplet Deposition Apparatus

The present invention relates to droplet deposition apparatus, in particular ink jet printheads.

The drive in drop-on-demand inkjet printing towards higher resolution requires increased density both of ink ejection nozzles and the associated drive circuitry, with the heating problems that this brings. Similarly, the trend towards ever greater printhead widths places correspondingly greater demands on heat management within printheads. Thermal ("bubble jet") printheads benefit in this regard from having their drive circuitry in close contact with the ink, which has a cooling effect. This is offset, however, by the need for special measures to maintain the electrical integrity of the circuitry in the ink environment.

It is an object of the present invention to prevent, in a simple manner, the drive circuitry of a printhead from overheating without at the same time risking its electrical integrity.

Accordingly, the present invention consists in droplet deposition apparatus comprising a fluid chamber having actuator means actuable by electrical signals to effect ejection of droplets from the fluid chamber;
drive circuit means for supplying the electrical signals;
conduit means for supplying droplet fluid to said fluid chamber;

the drive circuit means being in substantial thermal contact with said conduit means so as to transfer a substantial part of the heat generated in said drive circuit to said droplet fluid.

Arranging the drive circuit means in such a manner conveniently allows the ink in the printhead to serve as the sink for the heat generated in the drive circuitry - thus preventing overheating - whilst avoiding the problems with electrical integrity that might occur were the integrated circuit packaging containing the circuitry allowed to come into direct contact with the ink.

Where the apparatus incorporates first conduit means for supplying droplet fluid into said fluid chamber and second conduit means for leading droplet fluid out of said fluid chamber, the drive circuit means may advantageously be thermally connected to the second conduit means. This provides the most direct route out of the printhead for the heat generated in the chip and, in the event that the heat produced by the chip varies significantly during operation, minimises any variation in the temperature of the ink in the fluid chamber itself. As is known, e.g. from WO97/35167, such temperature variation can give rise to variations in droplet ejection velocity and consequent dot placement errors in the printed image.

Where the drive circuit is incorporated within an integrated circuit package of substantially cuboid form in which at least some of the faces are rectangles each

having a surface area, a face other than that face having the smallest surface are may advantageously be arranged so as to lie substantially parallel to, and to be in substantial thermal contact with, the direction of fluid flow in that part of the conduit closest to said face. Such an arrangement ensures significant heat transfer to the droplet fluid. Preferably, that face having the greatest surface area is arranged so as to lie parallel to the direction of fluid flow. Circuit architecture permitting, such an arrangement should generally maximise heat transfer from the circuitry.

According to a second aspect of the invention, there is disclosed droplet deposition apparatus having:
a plurality of droplet ejection units, each unit comprising a plurality of fluid chambers associated with actuator means actuable to eject a droplet from a respective one of a plurality of nozzles arranged in a row;
a support member for supporting said units side by side in the direction of the respective nozzle rows, the member further comprising at least one droplet fluid passageway communicating with a plurality of said ejection units and arranged so as to distribute heat substantially evenly throughout the support cross-section taken perpendicular to the direction of the respective nozzle rows.

The substantially even distribution of heat throughout the cross-section of the support that is achieved with such arrangement reduces thermally-induced strains that might otherwise distort the printhead. Such distortion would become

more pronounced as the width of the printhead increased, for example, to that of a page (typically 12.6 inches for the American "Foolscap" standard) and would occur regardless of whether a plurality of narrow ejection units or a single wide ejection unit were used in conjunction with the support.

Accordingly, the second aspect of the invention also consists in deposition apparatus having:

at least one droplet ejection unit comprising a plurality of fluid chambers associated with actuator means actuable to eject a droplet from a respective one of a plurality of nozzles, said plurality of nozzles being arranged in a row and extending the width of a substrate onto which droplets are to be deposited;

a support member for said at least one unit that extends said width of a substrate and that comprises at least one droplet fluid passageway communicating with said plurality of fluid chambers and arranged so as to distribute heat substantially evenly throughout the support cross-section taken perpendicular to the direction of the respective nozzle rows.

Advantageously, the droplet fluid passageway may occupy the majority of the area of the support when seen in cross-section. Alternatively or in addition, the passageway may comprise respective portions for the flow of droplet fluid in to and out of the fluid chamber. Such flow will aid the transfer of heat from the fluid chamber (where the main source of heat - the actuator means - is located) to the remainder of the support, thereby reducing temperature differentials.

To provide effective support for the droplet ejection unit(s), the cross-section of support member is preferably wider in the direction of ink ejection from the nozzles than in the direction perpendicular thereto.

Heat distribution will of course be facilitated by constructing the support member from a material - such as aluminium - having a high thermal conductivity. Such a material also has advantages as regards manufacture and cost. Problems arise, however, where the ejection units that the member is designed to support are made of a material having a coefficient of thermal expansion that is significantly different to that of the support. This will be the case with the ejection units comprising channels formed in a body of piezoelectric material (typically lead zirconium titanate, PZT) described hereafter. As will be readily appreciated, differential expansion - particularly in the direction of the nozzle rows in a "pagewide" device - may lead to distortion and/or breakage of ink seals, actuator components, electrical contacts, etc.

A solution to the above problem is comprised in a third aspect of the present invention, namely droplet deposition apparatus comprising:

a fluid chamber defined at least in part by a structure of a first material having a first coefficient of thermal expansion, said chamber being associated with actuator means actuable to eject a droplet from the chamber and having a port for inlet of droplet fluid;

a support member for said structure of said fluid chamber and including a passageway for supply of droplet liquid to said port, the support member being defined at least in part by a second material having a second coefficient of thermal expansion greater than said first coefficient; and

resilient bonding means to bond the structure to the support member without transferring thermal deformation of the support member to said structure of a first material.

In the example described hereafter, an adhesive rubber pad is used to bond a support member of extruded aluminium to a fluid chamber structure comprising a channel formed in a body of PZT and closed by cover member of a material, such as molybdenum, that is thermally matched to the PZT. Forming ink supply ports in the cover and ink ejection nozzles in the channelled component gives a particularly compact design having a low component count.

Further advantageous embodiments of the invention are set out in the description, drawings and dependent claims.

The invention will now be described by way of example by reference to the following diagrams, of which:

Figure 1 is a perspective view from the front and top of a first embodiment of the invention;

Figure 2 is a perspective view from the rear and top of the printhead of figure 1;

Figure 3 is a sectional view of the printhead taken perpendicular to the direction of extension XX of the nozzle rows XX;

Figure 4 is a perspective view from the top and above of one end of the printhead of figure 1;

Figure 5 is a sectional view taken along a fluid channel of an ink ejection module of the printhead of figure 1;

Figure 1 illustrates a first embodiment of a printhead 10 according to the present invention. The example shown is a "pagewide" device, having two rows of nozzles 20,30 that extend (in the direction indicated by arrow 100) the width of a piece of paper and which allows ink to be deposited across the entire width of a page in a single pass. Ejection of ink from a nozzle is achieved by the application of an electrical signal to actuation means associated with a fluid chamber communicating with that nozzle, as is known e.g. from EP-A-0 277 703, EP-A-0 278 590 and, more particularly, UK application numbers 9710530 and 9721555 incorporated herein by reference. To simplify manufacture and increase yield, the "pagewide" row(s) of nozzles are made up of a number of modules, one of which is shown at 40, each module having associated fluid chambers and actuation means and being connected to associated drive circuitry (integrated circuit ("chip") 50) by means e.g. of a flexible circuit 60. Ink supply to and from the printhead is via respective bores (not shown) in endcaps 90.

Figure 2 is a perspective view of the printhead of figure 1 from the rear and with endcaps 90 removed to reveal the supporting structure 200 of the printhead incorporating ink flow passages 210,220,230 extending the width of the printhead. Via a bore in one of the endcaps 90 (omitted from the views of figures 2 and 3), ink enters the printhead and the ink supply passage 200, as shown at 215 in figure 2. As it flows along the passage, it is drawn off into respective ink chambers, as illustrated in figure 3, which is a sectional view of the printhead taken perpendicular to the direction of extension of the nozzle rows. From passage 220, ink flows into first and second parallel rows of ink chambers (indicated at 300 and 310 respectively) via aperture 320 formed in structure 200 (shown shaded). Having flowed through the first and second rows of ink chambers, ink exits via apertures 330 and 340 to join the ink flow along respective first and second ink outlet passages 210,230, as indicated at 235. These join at a common ink outlet (not shown) formed in the endcap located at the opposite end of the printhead to that in which the inlet bore is formed.

Each row of chambers 300 and 310 has associated with it respective drive circuits 360, 370 which, in accordance with the present invention, are mounted in substantial thermal contact with that part of structure 200 acting as a conduit and which defines the ink flow passageways so as to allow a substantial amount of the heat generated by the circuits during their operation to transfer via the conduit structure to the ink. To this end, the structure 200 of the embodiment of figures 1-3 is made of a material having good thermal conduction properties. Of

such materials, aluminium is particularly preferred on the grounds that it can be easily and cheaply formed by extrusion. Circuits 360,370 are then positioned on the outside surface of the structure 200 so as to lie in thermal contact with the structure, thermally conductive pads or adhesive being optionally employed to reduce resistance to heat transfer between circuit and structure.

In the embodiment shown, the cuboid drive circuit dies 360,370 are arranged such that a largest (rectangular or square) surface of each die lies substantially parallel to the direction (indicated at 235) of fluid flow in the respective parts of the conduits 210,230 lying closest to those surfaces. This helps maximise heat transfer between circuit and ink, which is also facilitated by minimising the thickness of the structure separating the ink channel and the circuit, as well as by making the structure of a material having good thermal conduction.

Reference is now made to figure 4, which is a perspective view from the top and above of one end of the printhead with all but one of the modules 40 having been removed to show external and internal details of structure 200 more clearly. Recesses 500 to accommodate drive circuits 370 and lips 510,520 to retain - further circuit boards 530 populated with those components not suited to incorporation into the drive circuits 370. Forming rear lip 520 on a separate component 540, as shown in figure 4, allows these boards to be clamped into place by the action of fastening means, for example screws inserted through holes 240 shown in figure 2 and engaging with a bar (not shown) residing in

channel 550. Preferably the bar is made of a strong material, such as steel, able to accommodate screw threads and reinforce aluminium structure 200, particularly against the forces generated when installing and connecting the printhead.

In the present embodiment, further circuit board is also formed with pins (figure 3, 420) for supply of power and data into the printhead and with posts 560 for supplying power and data - suitably processed - to the drive circuits 370 via flexible connectors 570. Such connection techniques are well known in the art and will not therefore be discussed in further detail.

As explained above, heat generated in the drive circuits is transferred to the ink whence it is distributed about the structure 200 as a result of the aforementioned ink flow paths. Heat generated in the ink chambers by the associated actuator means is also distributed in this manner. As a result, any temperature differentials that arise within structure 200 are small and do not give rise to significant internal forces and/or distortion.

However, the overall warming of the printhead during operation may lead to differential expansion of the structure 200 and the body in which the fluid chambers 300,310 are formed where these two members are of materials having significantly differing coefficients of thermal expansion, C_{TE}. This is the case in

the present embodiment having fluid chambers formed in a body of piezoelectric material in accordance with the aforementioned UK application number 9721555.

As illustrated in figure 5, which is a sectional view taken along a fluid channel of a module 40, channels 11 are formed in a base component 860 of piezoelectric material so as to define piezoelectric channel walls therebetween. These walls are subsequently coated with electrodes to form channel wall actuators as are known e.g. from the aforementioned EP-0-0 277 703, a break in the electrodes at 810 allowing the channel walls in either half of the channel to be operated independently by means of electrical signals applied via electrical inputs (flexible circuits 60).

Each channel half is closed along a length 600,610 by respective sections 820,830 of a cover component 620 which is also formed with ports 630,640,650 that allow ink to be supplied to and from each channel half for cleaning and heat removal purposes, as is generally known. As is also known, cover component 620 is preferably made of a material that is thermally matched to the piezoelectric material of the channelled component. Ink ejection from each channel half is via openings 840,850 that communicate the channel with the opposite surface of the piezoelectric base component to that in which the channel is formed. Nozzles 870,880 for ink ejection are subsequently formed in a nozzle plate 890 attached to the piezoelectric component.

To avoid the distortion of the printhead that might otherwise occur as a result of the differing thermal expansion characteristics of the piezoelectric material of the fluid chambers and the aluminium of the structure 200, tie rods may be inserted in bores 580 in the structure and tightened so as to keep structure 200 in compression. Although any material having a value of C_{TE} less than that of the structure - steel in the case of an aluminium structure - is suitable for the tie rods, it will be appreciated that low values of C_{TE} are to be preferred.

In addition, cover component 620 may be attached to structure 200 by means of a resilient bond - adhesive coated rubber is shown at 430 in figure 3 - so as to allow any relative expansion that may occur in spite of the presence of tie rods (and which may be of the order of 0.3mm over a typical 12.6" length of a printhead) to take place at this less critical interface rather than generating stresses and deformations in the printhead module 40 itself. As shown in figure 4, cover 620 may be sit in a well 590 formed in structure 200 and may additionally extend to either side of the printhead to provide mounting surfaces for the printhead. Molybdenum, which has high strength and thermal conductivity in addition to being thermally matched to PZT, has been found to be a particularly suitable material for the cover.

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Claims

1. Droplet deposition apparatus comprising a fluid chamber having actuator means actuable by electrical signals to effect ejection of droplets from the fluid chamber;
drive circuit means for supplying the electrical signals;
conduit means for supplying droplet fluid to said fluid chamber;
the drive circuit means being in substantial thermal contact with said conduit means so as to transfer a substantial part of the heat generated in said drive circuit to said droplet fluid.

2. Apparatus according to claim 1 and further incorporating first conduit means for supplying droplet fluid into said fluid chamber and second conduit means for leading droplet fluid out of said fluid chamber.

3. Apparatus according to claim 2, wherein said drive circuit means is thermally connected to the second conduit means.

4. Apparatus according to any previous claim and wherein said drive circuit means is incorporated within an integrated circuit package of substantially cuboid form in which at least some of the faces are rectangles each having a surface area, a face other than that face having the smallest surface being arranged so

as to lie substantially parallel to, and to be in substantial thermal contact with, the direction of fluid flow in that part of the conduit closest to said face.

5. Apparatus according to claim 5, wherein that face having the greatest surface area is arranged so as to lie parallel to the direction of fluid flow.

6. Droplet deposition apparatus having:
a plurality of droplet ejection units, each unit comprising a plurality of fluid chambers associated with actuator means actuable to eject a droplet from a respective one of a plurality of nozzles arranged in a row;
a support member for supporting said units side by side in the direction of the respective nozzle rows, the member further comprising at least one droplet fluid passageway communicating with a plurality of said ejection units and arranged so as to distribute heat substantially evenly throughout the support cross-section taken perpendicular to the direction of the respective nozzle rows.

7. Droplet deposition apparatus having:
at least one droplet ejection unit comprising a plurality of fluid chambers associated with actuator means actuable to eject a droplet from a respective one of a plurality of nozzles, said plurality of nozzles being arranged in a row and extending the width of a substrate onto which droplets are to be deposited;
a support member for said at least one unit that extends said width of a substrate and that comprises at least one droplet fluid passageway communicating with

said plurality of fluid chambers and arranged so as to distribute heat substantially evenly throughout the support cross-section taken perpendicular to the direction of the respective nozzle rows.

8. Apparatus according to claim 6 or 7, wherein the droplet fluid passageway occupies the majority of the area of the support when seen in cross-section

9. Apparatus according to any of claims 6 to 8, wherein the passageway includes respective portions for the flow of droplet fluid in to and out of the fluid chamber

10. Apparatus according to any of claims 6 to 9, wherein the cross-section of support member is preferably wider in the direction of ink ejection from the nozzles than in the direction perpendicular thereto.

11. Apparatus according to any previous claim, wherein the support member comprises a material having a high thermal conductivity.

12. Droplet deposition apparatus comprising:
a fluid chamber defined at least in part by a structure of a first material having a first coefficient of thermal expansion, said chamber being associated with actuator means actuable to eject a droplet from the chamber and having a port for inlet of droplet fluid;

FIG. 1

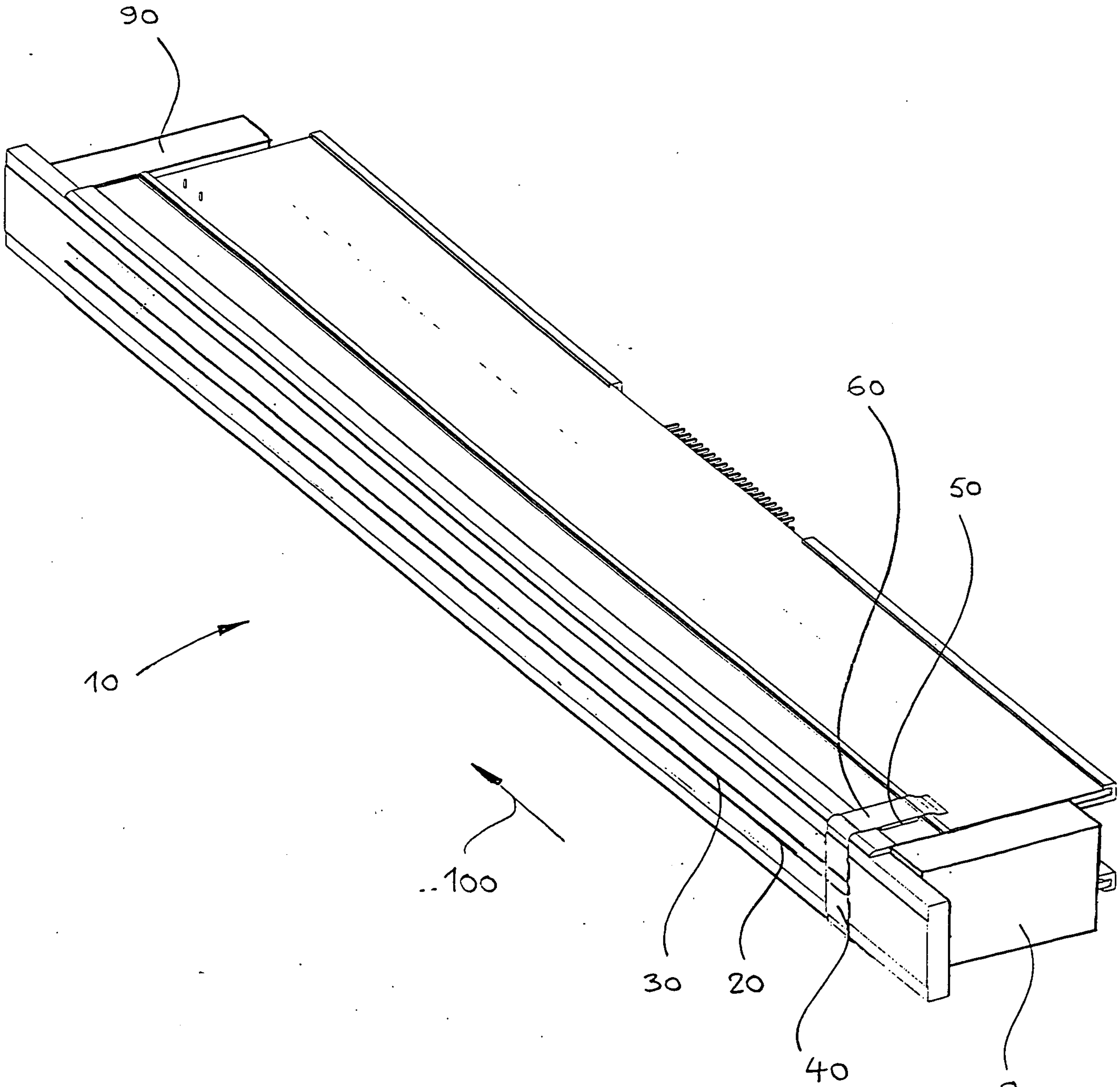

FIG. 2

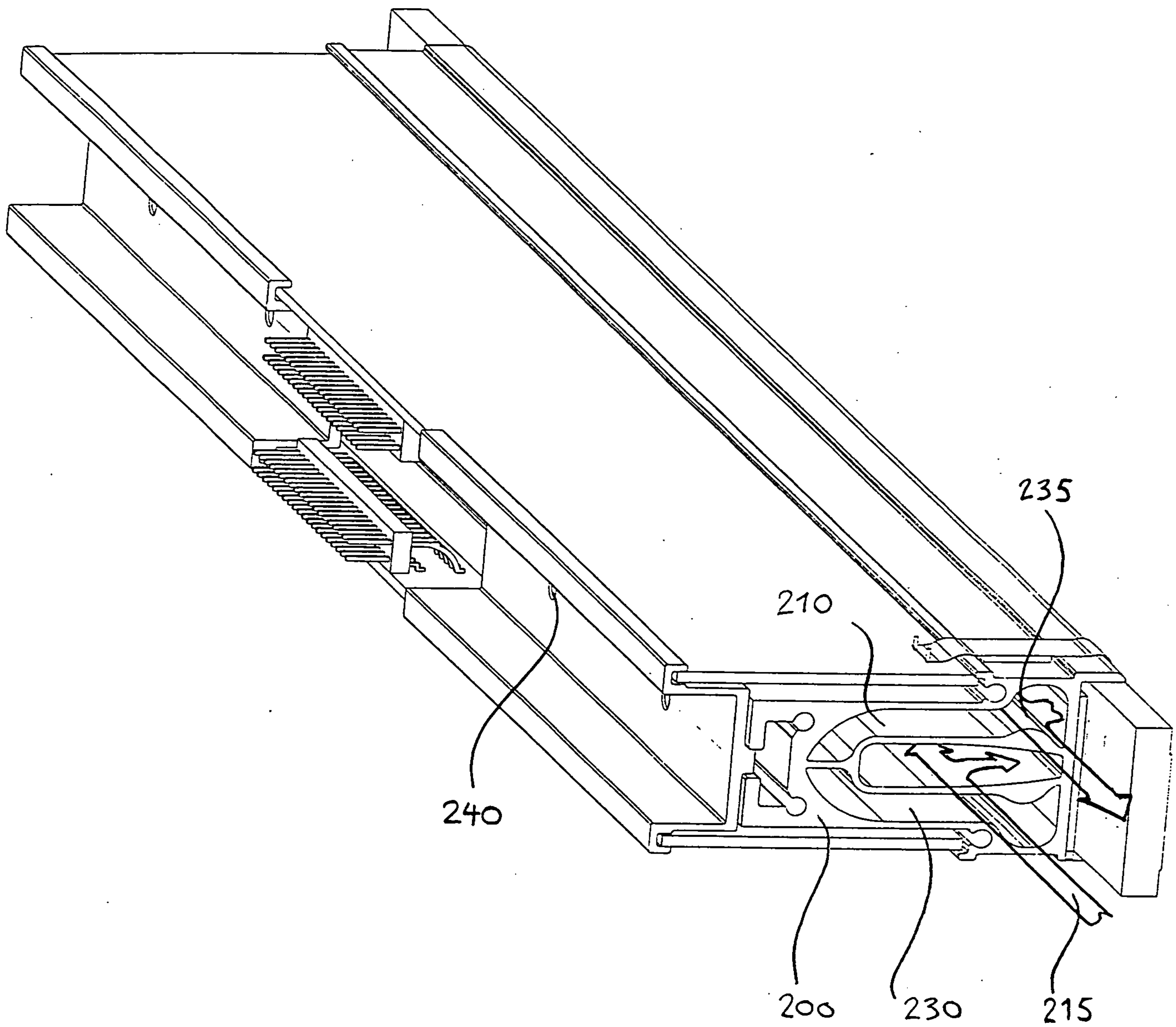

FIG. 3

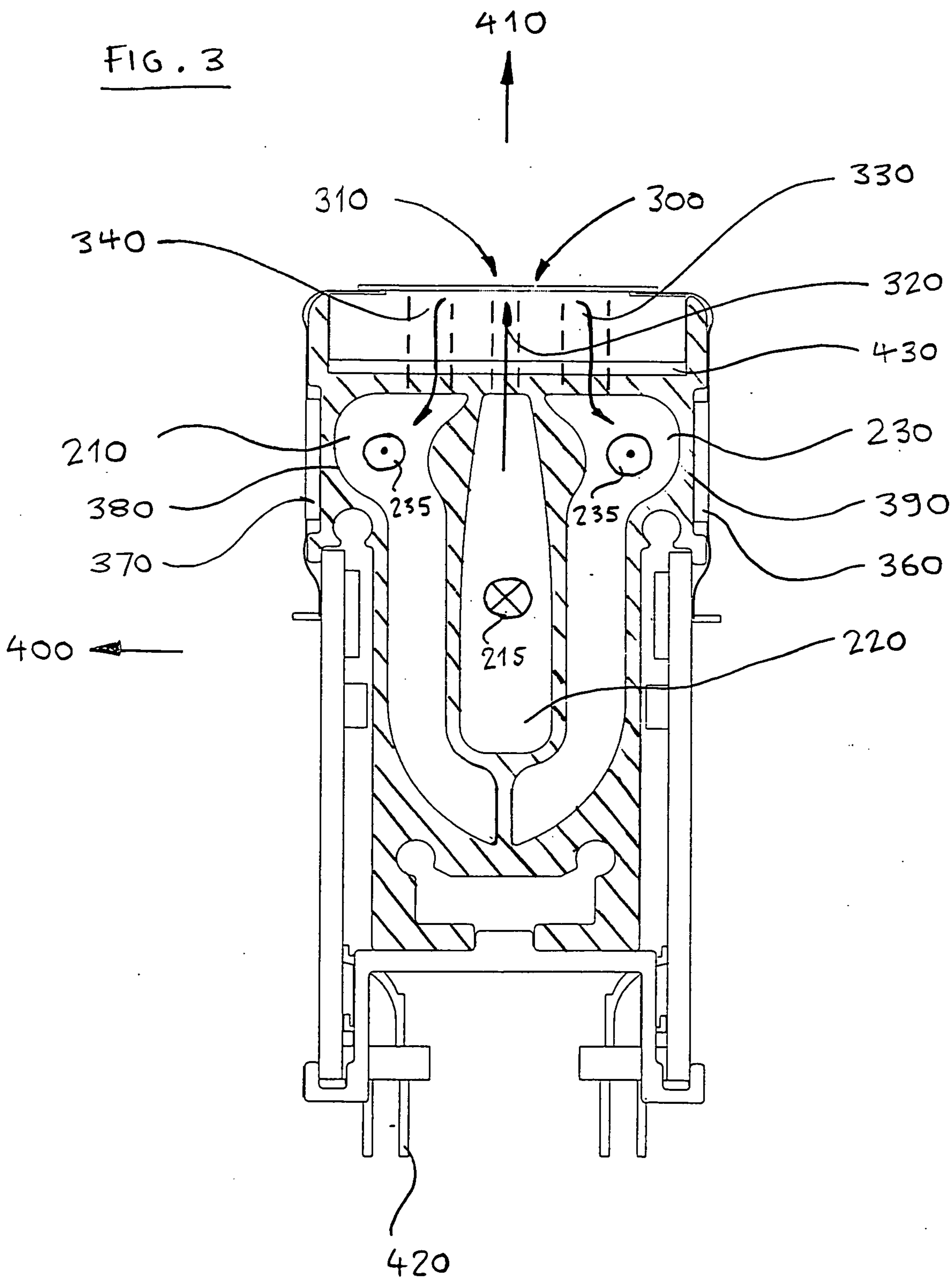

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FIG. 4

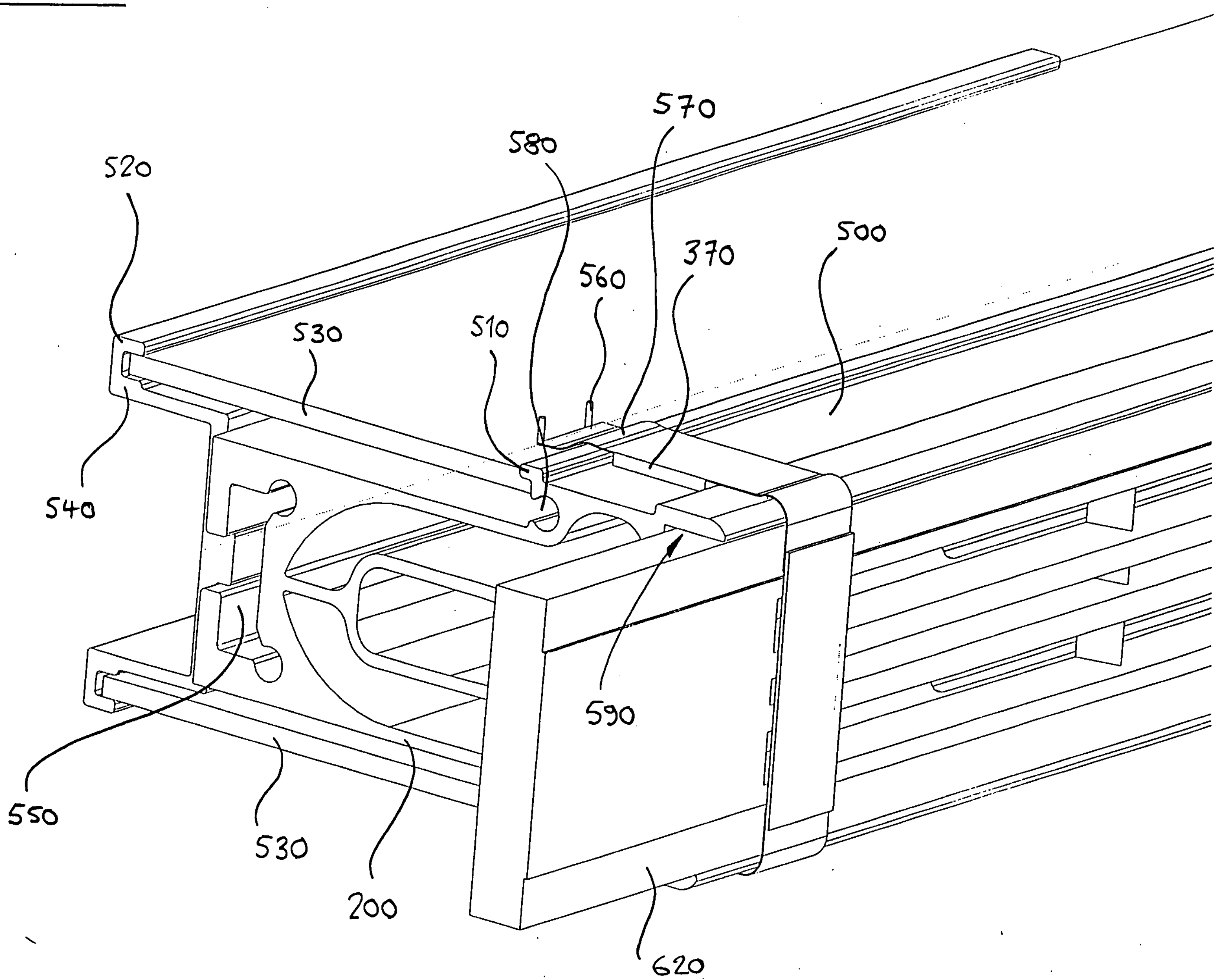
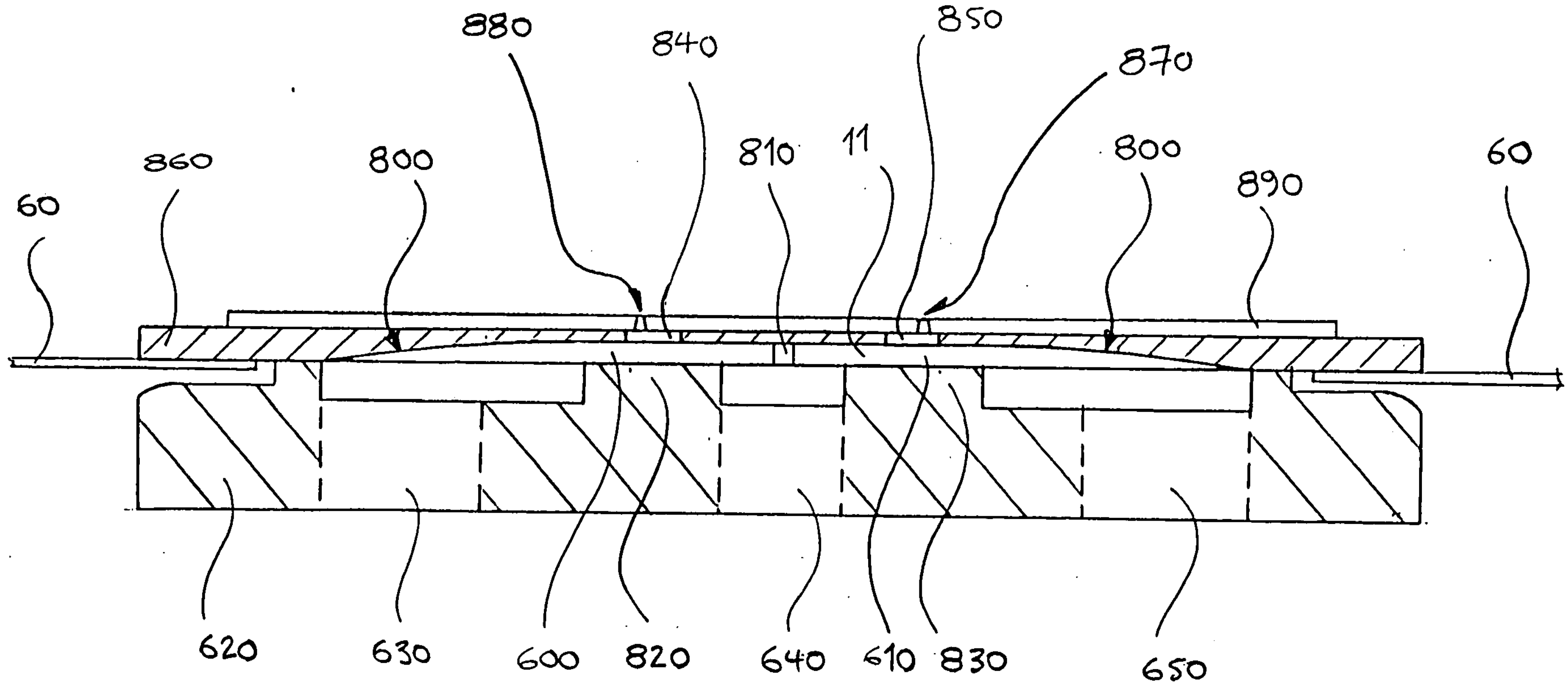


FIG. 5



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